Human Survivability (HS) Element Of The NASA Safety Initiatives Portfolio

ASIST Transition "Sweatshop"
Supporting Information On
Human Survivability

May 14-15, 1997
Building 1218, Room 107

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Hampton, VA

ASIST
Human Survivability Program Outline

1.0 Introduction/Background

2.0 The Human Survivability Team(s)

3.0 Team Charter/Scope

4.0 Approach

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- *Objectives*
- *Investments*

NASA's Aeronautics Safety Investment Strategy

Human Survivability Subteam

1.0 Introduction/Background

On February 12, 1997, President Clinton endorsed the recommendation of the White House Commission on Aviation Safety and Security that the rate of aviation accidents be reduced by a factor of five within a decade. He also announced that NASA will support this national safety goal by re-directing $500M of research funding over five years.

On February 18, 1997 NASA held the first workshop (in a series of four) to initiate Aeronautics Safety Investment Strategy Team (ASIST) activities. The team was chartered to clearly define an aviation safety investment strategy for NASA and to delineate programmatic investment options to achieve the stated safety goal. The ASIST members are drawn from NASA, other government agencies (FAA, DoD, NWS), industry and industry groups. Five sub-teams were formed to focus on areas of Human Error; Flight

Critical Systems & Information Integrity; Weather; Aviation System-wide Monitoring, Simulation & Modeling; and Human Survivability. The sub-teams are to deliver final proposals/plans at a workshop to be convened on April 15-17, 1997.

2.0 Human Survivability Sub-Team(s)

Human Survivability Team (In Time)
Attendance

Workshop 1-- February 19-21, 1997

Name	Organization
Huey Carden	NASA LaRC
LTC Bruce Bailey	DoD Army
Dr. James Hicks	DoD Army Safety Center
Van Gowdy	FAA/CAMI
Dick Hill	FAA Tech Center
Gus Sarkos	FAA Tech Center
Jerry Hordinsky	FAA/CAMI
Gary Frings	FAA-TC

Workshop 2 -- March 6 -7, 1997

Bill Shook	Douglas Aircraft
Mike Norman	McDonnell Douglas
George Neat	DOT Volpe Center
Ron Welding	ATA
Jim Hicks	Army Safety Center
Huey Carden	NASA LaRC
Mike Downs	FAA/ACE
Jeff Marcus	FAA/CAMI
Jerry Hordinsky	FAA/CAMI
Gary Frings	FAA-TC

Workshop 3 -- March 24 -28, 1997

Diane Sandwick	Boeing Payloads
Todd Curtis	Boeing Airplane Safety Eng.
Bill Shook	Douglas Aircraft Cabin Safety
Steve Hooper	WSU-NIAR
George Neat	DOT Volpe Center
Ronda Ruderman	Assn. of Flight Attendants
RaNae Contarino	NAWC Pax
Gregory Feith	NTSB-DCA
Huey Carden	NASA LRC
Jeff Marcus	FAA/CAMI

Workshop 3 -- March 24 -28, 1997

Name	Organization
Stephen Soltis	FAA Resource Specialist
Gary Frings	FAA-TC
Robert Friedman	NASA LeRC

Workshop 4 -- April 15-17,1997

Name	Organization
Bruce Holmberg	ARCCA
Christopher Witkowski	Assoc. Flight Attendants
Maynard M. Foster	Assoc. Flight Attendants
Dr. Jonathan Kaufman	DoD NAWCAD
Paul Kinzay	DoD Naval Safety Center
Ric Loeslien	DoD NAWCAD
RaNae Contarino	DoDNAWCADPax
Martin Lentz	DoD UASF-WL/FIVS
George Neat	DOT/Vople Center
Gary Frings	FAA TC
Jeff Marcus	FAA/CAMI
Jerry Hordinsky	FAA/CAMI
Bill Shook	McDonnell Douglas
Huey Carden	NASA LaRC
Howard Ross	NASA LeRC
David Myres	NAVMAR
Maria Thorpe	NAWCAD Pax
Matt McCormick	NTSB

3.0 Team Charter/Scope

National Goal and NASA Goal:

"Reduce aviation fatalities and aircraft accident rates by a factor of five within ten years and by a factor of ten within twenty years."where "To reduce aviation fatalities and aircraft accident rates" means to reduce the projected accident rates and fatalities for each class of civil aircraft operations within the US and the projected accident rate and fatalities for US-made commercial aircraft and US airline operations internationally.

Human Survivability is One Subtask Focus Area In The NASA Segment of the Overall Program Thrusts for Safety. The Tacit Assumption Generally Made With Human Survivability Is That An "Accident Has Already Occurred". If A "Fatality" Occurs And Human Survivability Had Provided Significantly To The Survival Of Occupants, It Is Still Categorized As A "Fatal Accident". Therefore, The Human Survivability Element Can Do Little to Help Reduce the Fatal Accident Rate without 100% success of preventing fatalities. Thus,

The charter of the Human Survivability Sub-Team is to define a NASA investment strategy to help achieve the national aviation safety goals by significantly reducing the number of future fatalities/serious injuries in aviation accidents. As a goal, the team should consider those activities needed to increase human survivability in "Potentially Survivable Accidents" in all aviation segements.

It is proposed that the scope of the term "human survivability" for this team be defined as conditions that are life threatening on an aircraft in flight or on the ground. Included are all "potentially survivable" accidents currently producing significant fatalities and serious injuries but excluded are accidents which clearly were non-survivable from post crash analysis. These survivable accident fatalities represent a significant percentage of commercial transport, general aviation (GA) and rotorcraft fatalities.

4.0 Approach

To accomplish these tasks the human survivability sub-team will follow the proposed course of action:

1. *Agree on the definitions proposed or suggest modifications.*
2. *Agree on the charter proposed or suggest modifications.*
3. *Identify critical aviation human survivability issues that cause or contribute to current fatalities/serious injuries.*
4. *Identify potential human survivability issues that may be important in the changing future aviation system.*
5. *Identify what broad or specific solution strategies could significantly reduce the current and future fatalities/serious injuries.*
6. *Identify aviation programs currently underway which address these solution strategies.*
7. *Identify and prioritize those human survivability issues that can be addressed by research and technology developments*
8. *Develop and propose NASA investment strategies.*

5.0 Summary of Human Survivability Factors

The following charts were initially used in identifying and assembling major issues, current and future, affecting human survivability. The headquarters ASIST team leaders suggested the categories for assigning potential solution paths in this process. The catorigazation was done by whether the Issue was one basically that nothing about it could be done, or potential solutions exist but expensive and R&T could help, and finally if new technology, ideas etc. would be required. In developing the investment strategy, the sub-team identified four human survivability issues: (1) Fire, (2) Crashworthiness, (3) Evacuation, and (4) Occupant Protection as focus areas for potentially reducing fatalities/injuries in the survivable but fatal accident rate statistic. As shown in the charts, sub-issues under each of the four major Human Survivability Issues were identified as to being current and/or future issues and what aviation sector (GA, rotorcraft or transport) the issue affects or will affect.__

Current and Future Issues :

FIRE (ISSUES)	*CURRENT*	*PATH(CURRENT)*	*FUTURE*	*AC TYPE*
1. AC Materials	*X*	*3*	*X*	*R, G, T*
toxicity				
flammability				
2. Oxygen Systems	*X*	*3*	*X*	*G, T*
flammability	*X*	*3*		
requirement for	*X*	*3*		
alternative systems	*X*	*2*		
quantity, sufficiency			*X*	
3. Crash Resistant Fuel Systems(Main/Aux)	*X*	*3*		*R, G, T*
rotorcraft		*3*		
transport/GA		*2*		
4. Fire-Safe Fuels	*X*	*2*		*R, T*
5. Suppression/detection	*X*	*3*		*R, G, T*
Halon replacement				

Path Code (Initially Suggested by ASIST Leadership):

1. Important Issues That We Can't Can't Do Anything About.

2. Important Issues That Have Potential Solutions That Aren't Affordable (But My Be Through R&T).

3. Important Issues That Need New Technology, Ideas, Etc.

AC Type : G -- General Aviation; R -- Rotorcraft; T -- Transport

Current and Future Issues - Continued:

CRASHWORTHINESS (ISSUES)	*CURRENT*	*PATH(CURRENT)*	*FUTURE*	*AC TYPE*
1. Systems Approach to Crashworthiness				
- Metal/CompositesStructures/New Materials	*X*	*2/3*	*X*	*R, G, T*
crash behavior/intregity				
-Investigative tech. (crash recorders)				
energy absorption concepts				
database				
analysis/modeling				
- Crashworthiness Design Criteria	*X*	*3*		*R, G, T*
Biomechanics(injury criteria)				
structural/breaks,				
e.g., child protection, advanced restraints				
cabin safety				
mass items				

2.	*Unique Configurations*	*X*		*X*	*T*

Path Code (Initially Suggested by ASIST Leadership)

1. Important Issues That We Can't Can't Do Anything About.

2. Important Issues That Have Potential Solutions That Aren't Affordable (But My Be Through R&T).

3. Important Issues That Need New Technology, Ideas, Etc.

AC Type : G -- General Aviation; R -- Rotorcraft; T -- Transport

Current and Future Issues - Continued:

EVACUATION (ISSUES)		*CURRENT*	*PATH(CURRENT)*	*FUTURE*	*AC TYPE*
1.	*Water Related Survivability*	*X*	*2*	*X*	*R, G, T*
	(planned/unplanned)				
2.	*Multi-deck/Multi-aisle Aircraft*			*X*	*T*
3.	*Non-cylindrical Designs*			*X*	*T*
4.	*Post Crash Rescue*	*X*	*3*	*X*	*T*
	crash fire rescue				

	improved treatments				
	of injured/burned pax				
5.	*Evacuation Design Guidelines*	*X*	*3*	*X*	*T*
	modeling				
	slides - human factors				
	lighting				
	disabled pax				
	human dynamics				
	people,procedures				
6.	*Advanced Evacuation Designs*			*X*	*T*

Path Code (Initially Suggested by ASIST Leadership)

1. Important Issues That We Can't Can't Do Anything About.

2. Important Issues That Have Potential Solutions That Aren't Affordable (But My Be Through R&T).

3. Important Issues That Need New Technology, Ideas, Etc.

AC Type : G -- General Aviation; R -- Rotorcraft; T -- Transport

Current and Future Issues - Concluded:

OCCUPANT PROTECTION (ISSUES)	*CURRENT*	*PATH(CURRENT*	*FUTURE*	*AC TYPE*
1. *Baro-Trauma - High Speed Civil Transport*			*X*	*T*
(Pressure injury)				

2.	*Hypoxia*	*X*	*3*	*X*	*T*
	(Oxygen deprivation)	*(crew)*		*(crew/pax)*	
3.	*Protective Breathing Equipment*	*X*	*3*	*X*	*R, T*
	(Crew/Pax) smoke protection				

Path Code (Initially Suggested by ASIST Leadership)

1. Important Issues That We Can't Can't Do Anything About.

2. Important Issues That Have Potential Solutions That Aren't Affordable (But My Be Through R&T).

3. Important Issues That Need New Technology, Ideas, Etc.

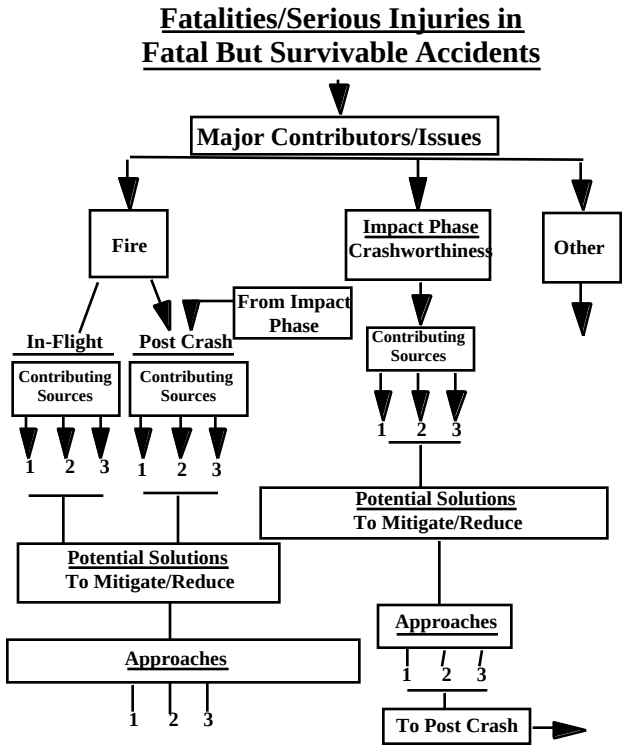
AC Type : G -- General Aviation; R -- Rotorcraft; T -- Transport

6.0 Process/Statistics and Prioritized Sub-Focus Issues

Potential Approaches

The following charts illustrate the approach for organizing potential activities/developments in aviation human survivability and safety. As shown in the Process Chart, major contributors to the fatalitieis/serious injuries as they relate to the four issues were processed through and expanded to include known contributing sources to, for example, fire or crashworthiness. Potential solutions and /or approaches to address the factors were then discussed.

Process:


Fatalities/Serious Injuries in
Fatal But Survivable Accidents
Major Contributors/Issues
Fire
Impact Phase
Crashworthiness
Other
From Impact
Phase
In-Flight
Post Crash
Contributing
Sources
Contributing
Sources
Contributing
Sources
1 2 3
1 2 3
1 2 3
Potential Solutions
To Mitigate/Reduce
Potential Solutions
To Mitigate/Reduce
Approaches
Approaches
1 2 3
1 2 3
To Post Crash

Accident Statistics And Expert Advice Were Used To Guide Planning Efforts And Priority In Human Survivability

Aircraft Category →	Transport World Wide 82-94(14 yr)	Transport World Wide 82-94 (14 yr)
Fatal Accident Area	Number of Accidents	On Board Fatalities
Landing	173	290
On-Ground Fire	93	1082
ATC Com.	61	2111
Maint. & Insp.	58	1560
CFIT	49	2890
Loss of Control	45	2632
Ground Ops	33	162
Engine/Crew	21	346
Approach	20	1257
TakeOff Conf.	13	243
Inflight Fire	12	673
Uncontained Engine	13	199

+ Additional

+ Expert(s)

1959-90

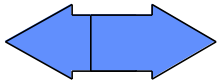
Accident Data Show:

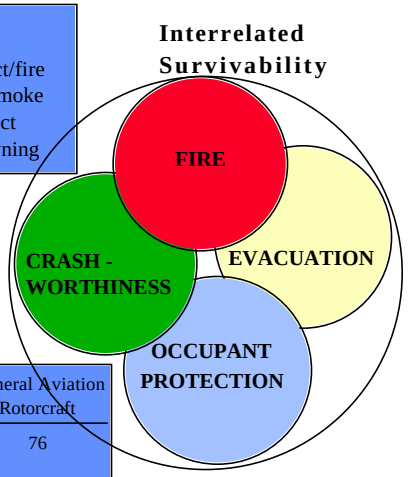
52% Nonsurvivable — 50% Impact/fire

3% 1-3 survivors — 27% Fire/smoke

45% survivable — 18% Impact

5% Drowning





1985-1995

Aircraft Category →	General Aviation-All	General Aviation Rotorcraft
Fatal with at least one survivor	701	76
Accidents with fire	2624	194
Fatal Accidents with fire	1588	101
Total Fatal Accidents	4979	359

During the discussions and planning by the Human Survivability Team, statistics (were possible) were used to develop a priority list of the efforts and allocations . The four areas affecting human survivability, fire, crashworthiness, evacuation, and occupant protection, are illustrated to be interrelated issues by the circles in a circle presentation on the chart. However, one difficulty, and a reason that collective judgement and expericence of Industry and Government experts were also used to develop a priority in the

process, is that statistics are categorized according to "what happened", not "why it happened". For most accidents, data is not available to allow exact determination of "what" caused the fatalities to occur other than a broad category such as fire, or impact, or human error, etc. Therefore relating sub issues or problems that contribute to the overall category of fire fatalities is generally not possible. The prioritization by the process illustrated her is shown below in the chart on the left for transport category aircraft and the chart on the right for the GA/Rotorcraft segements where one should note that the consensus was that fire and crashworthiness both were essentially number 1 in these aviation sectors.

Priority of Major Issues (Transport)		**Priority of Major Issues (GA/Rotorcraft)**	
1.	**Fire**	**1.**	**Fire**
2.	**Crashworthiness**	**1.**	**Crashworthiness**
3.	**Evacuation**	**3.**	**Evacuation**
4.	**Occupant Protection**	**4.**	**Occupant Protection**

The categories of potential solution paths that were considered by the team include Prevention, Detection, Mitigation, and Suppression of hazards which adversely affect human survivability in aircraft in the air or on the ground.

Prevention

The prevention element is aimed at those issues where research and development could provide remove or alter hazards that currently contribute negatively to human survivability. Systems approaches to crashworthiness design of cabin interiors, seats and restraints could also help prevent, mitigate and/or suppress fatalities. More economical, lighter systems could be developed as an integral part of the design process with development of crashworthiness design criteria for structure, restraints (including child protection), and airbags should be an area of focus.

Additionally, if appropriate materials were available and used on interiors of aircraft, a source of toxcity and flammability could potentially be prevented during fire incidents. Although fire blocking materials are used in cabin seats, the potential for improving those and expanding such capability to more of the interior of the aircraft is great. The potential payoff of this effort in both safety and survivabilty could be substantial. Both in-flight and post crash fires in potentially impact survivable accidents leads to toxicity

and flammability of materials and is a leader in causing fatalities. The capability to find materials that produce less toxins, are slower to burn, etc could provide additional time for escape to occupants and thus help prevent a potentially large percentage of fatalities.

Detection

Many hazardous events begin, in many instances, as local in nature. Research and development opportunities in this area might include as aircraft system-wide detection systems to warn of toxic invasion in the cabin or other areas. Occupant (personal) detection devices might allow early warning and action time. Such systems could provide the occupants and flight crew with additional information and earlier warning of potential hazardous developments.

Mitigation/Suppression

This area is intended to includes broad, system-wide developments and improvements which might significantly affect aviation safety and human survivability. Potential focus areas might include design of exits, slides and improved lighting and assessing

human dynamics (in emergency situations) could contribute to enhanced survivabilty. There could be tremendous improvements and safety gains from much of this type research and development.

Other activities in this area could include issues related to human evacuation such as development of analysis/simulation tools to allow systematic and scenario type studies for improving evacuation procedures and validation of such tools from ground based data.

Development of alternative system in new aircraft design for the current on-board oxygen (which can serve as a fire feed source) could be potential focus. Current systems do exist and are in limited use on some aircraft, but they are generally expensive and heavy. Additionally, research and development of more crash resistant fuel systems could help mitigate/suppress the hazard of post crash fires. Fuel spillage which feeds the fire that often accompany "impact survivable" accident lead to many fatalities.

In the area of occupant (personal) protection, other than that discussed under crashworthiness issues, could be research and development of easy to use protective devices for occupant protection from smoke inhalation. This could enhance human survivability through providing additional time for evacuation under hazardous cabin environments produced in post crash fire related accidents.

7.0 Current Assessment of Activities in The Four Major Human Survivability Issue Areas.

The next steps by the process was for the Human Survivability Team to use the collective experience and knowledge of government and industry members on the Human Survivability Sub-Team and data provided in plenary sessions on current NASA and FAA or Industry activities to make assessments of level of activites in the current issue areas. The four charts below summarize that assessment, in order, of FIRE, CRASHWORTHINESS, EVACUATION, AND OCCUPANT PROTECTION. The color code applies to all charts.

Statistics		Human Survivability			
	Current Issues R&D Assessment	GA	Rotorcraft	Transport	PRIORITY
	FIRE*				
	1. AC Materials				
*Reference Statistics Charts for Fatalities	Toxicity	1	1	2	5
	Flammability	1	1	2	
	2. Oxygen Systems				
	Alternative Sys.	1	1	1	
	Flammability	1	1	1	4
	Requirements fo	1	1	1	
	3. Crash Resistant Fuel Sys.				
	Main/Aux. Relate	1	1	2 to 3	1
	Failures				
	4. Fire-Safe Fuels				
	Flammability	1	1	1	3
	(Uncontained)	1	1	1	
	Fire Feed Source				

	5. Detection/Suppression Halon Replacement	1	1	3	2

1	Minimal or No R&D Efforts Underway or Funded
2	Moderate R&D Efforts Underway or Funded
3	Significant R&D Efforts Underway or Funded
	Not Applicable

Statistics	Human Survivability CRASHWORTHINESS*				
	Current R&D Assessment	GA	Rotorcraft	Transport	PRIORITY
	CRASHWORTHINESS*				
	1. Systems Approach to Crashworthiness Design	2 Overall)	1	1 (Overall)	1
*Reference	A. Metal/Composite Structures	2 (Overall)	1 (Overall)	1 (Overall)	
Statistics Charts for Fatalities	New Materials	2	1	1	
	Crash Behavior	2	1	1	
	Investigative Techn.	2	1	1	
	Integrity (break	2	1	1	
	EA Concepts	2	2	1	
	Database/(Adv. Recorders)	2	1	1	
	Analysis Modeling	2	1	1	
	B. Crashworthiness Design Criteria	2 (Overall)	1- (Overall)	1+(Overall)	
	Structural	2	1	1	
	Occupant(Personal	2	1	2	

	Bio-Mech. (Inj. Criteria)	2	1	1	
	Cabin Safety				
	Seats	2	1	1	
	Restraints	2	2	2	
	Interiors (Bins/Mass)	2	1	3	
	Validated Modeling	2	2	1	
	2. Unique Configurations			1	2
	Combos				

Statistics	Human Survivability EVACUATION*				
	Current R&D Assessment	GA	Rotorcraft	Transport	PRIORITY
	EVACUATION*				
*Reference Statistics Charts for Fatalities	1.Water Related Survivability/ (Planned/unplanned)	1	2	1	2
	Structural issues				
	2. Post Crash Rescue	1	1	3	3
	Crash Fire Rescue				
	Treatments				
	(Injured/Burned)				
	3. Evacuation Design Guidelines				
	Modeling	1	1	2	
	Exits/Slides	1	1	2	
	Lighting	1	1	1	1
	Disabled Pax	1	1	1	
	Human Dynamics	1	1	1	

	(People In Emergencies) Procedures				
		1	1	2	

Statistics	Human Survivability Occupant Protection*				
	Current R&D Assessment	**GA**	**Rotorcraft**	**Transport**	**PRIORITY**
	OCCUPANT PROTECTION*				
	1.Protective Breathing Equipment	**1**	**2**	**1**	**2**
	Smoke Protection (Crew/passenger)				
***Reference Statistics Charts for Fatalities**	**2. Hypoxia**	**1**	**1**	**2**	**1**
	Oxygen deprivation (Crew)				

1	**Minimal or No R&D Efforts Underway or Funded**
2	**Moderate R&D Efforts Underway or Funded**
3	**Significant R&D Efforts Underway or Funded**

☐ Not Applicable

Summary of Priority of Sub-Focus Areas Within Major Priority Issues

Following the assessment process, the Human Survivability Team placed priorities on each of the major sub-focus issue areas within the major issue areas. Below are the results of that process.

Accident Mitigation -- Human Survivability (HS)

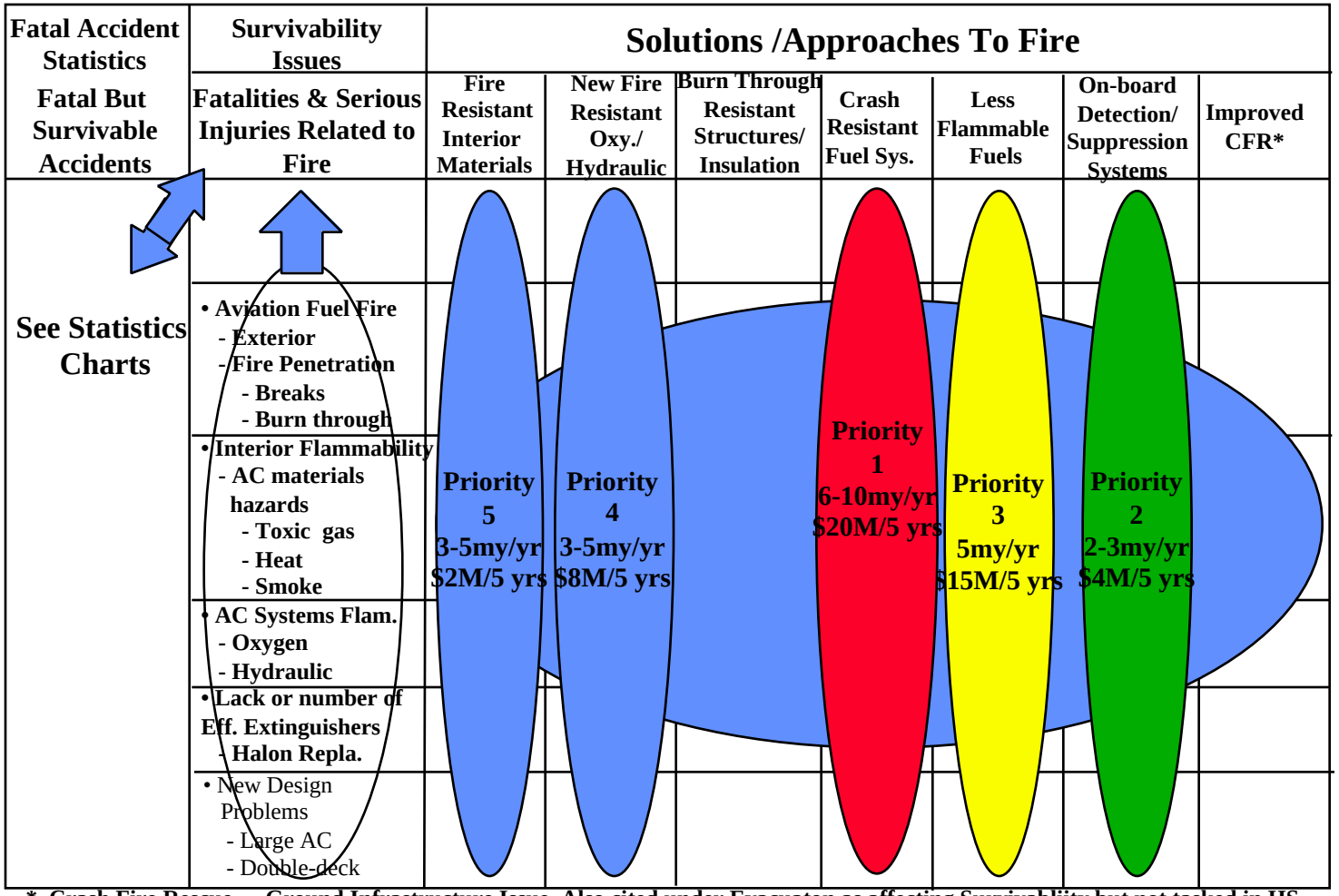
Prioritization Of Investment Areas Across The Major Four Human Survivability Issues

1. Fire Prevention (Pre/Post Incident)
   - **Crash Resistant Fuel Systems**
   - **Fire Safe Fuels/Systems**
   - **Fire Detection/Suppression**
   - **Fire Safe Materials**
2. Systems Approach To Crashworthiness
   - **Analytical Modeling**
   - **Metal/Composite Structures**
   - **Design Criteria/Guidelines**
   - **Biomechanics**
3. Systems Approach To Evacuation
   - **Modeling**
   - **Procedures/Training**
   - **Equipment**
   - **Exit/Slide Design Criteria**
   - **Guidelines**
4. (Occupant Protection) Maintaining Physiological Stability
   - **Alternate Ox Generation**
   - **Protection from Contaminants**
   - **Hypoxia**

With the assessments, priorities and sub-focus issue priorities available, the next chart is included only as an example to shows the methodology that was used to arrive at potential solutions in the four major Human Survivability Issues Areas. The team process was to identify underlying issues (In the Column Labeled Survivability Issues. As illustrated, the underlying factors roll up to the Fatalities/Serious Injuries that are reported in Accident Statistics (i.e Fire, Impact Etc.). However, after developing the potential solutions, the other ASIST Team members recommended that the (4) four individual charts be combined into one in which the Survivability Issues are listed as Fire, Crash (Impact) Evacuation, or Personal Protection Issues which, as stated, are the items listed at major contributing factors in Fatal Accident Statistics.

Human Survivability (HS) Proposed Investment

FIRE



* Crash Fire Rescue -- Ground Infrastructure Issue. Also cited under Evacuaton as affecting Survivabliity but not tasked in HS

8.0 Proposed Investments for Major Human Survivability Issues

Challenges/Objectives
Investments

Human Survivability (HS)

Challenges/Objectives
And
Proposed Investment Areas
In :

- **Fire**
- **Crashworthiness**
- *Evacuation*
- *Occupant Protection*

Accident Mitigation -- Human Survivability (HS)

Challenges/Objective of HS Investments

- **Challenges/Objective of Fire Investment:**

  To Identify, Support, and Develop Fire Prevention, Detection, and Suppression Concepts That Can Minimize Fire Hazards in Crashes and In-Flight Incidents.

- **Challenges/Objective of Crashworthiness Investment:**

  To Develop A Systems Approach To Crashworthiness DesignThat Includes Validated Analysis Methodology, New Structural Concepts And Materials, Safer Cabin Interiors Design, Advanced Restraint Equipment, Design And Injury Criteria To Enhance Crash Safety.

- *Challenges/Objective of Evacuation Investment :* :

  To Develop A Systems Approach For Evacuation That Includes Analysis/ Simulation Methodology, New Procedures ,Training, Equipment, And Design Criteria Which Can Enhance And Provide Means For More Timely Evacuation During Fire In Aircraft Accidents.

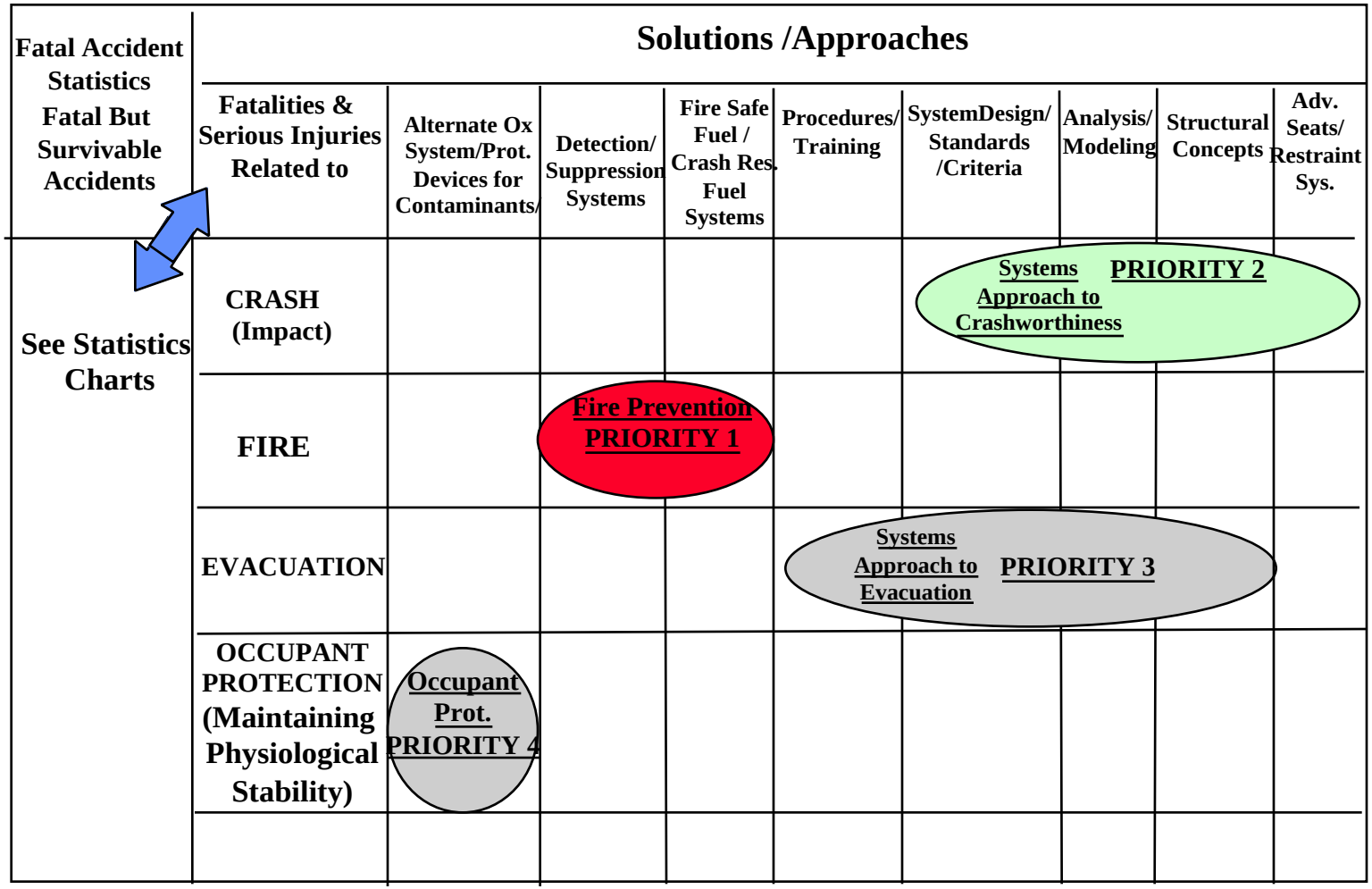
- *Challenges/Objective of Occupant Protection Investment:*

  To Develop Detection/Warning Means, New Procedures ,Training, And Equipment Which Can Provide Occupant Protection From Fire Related Hazards And Thus Provide Additional Evacuation Time.

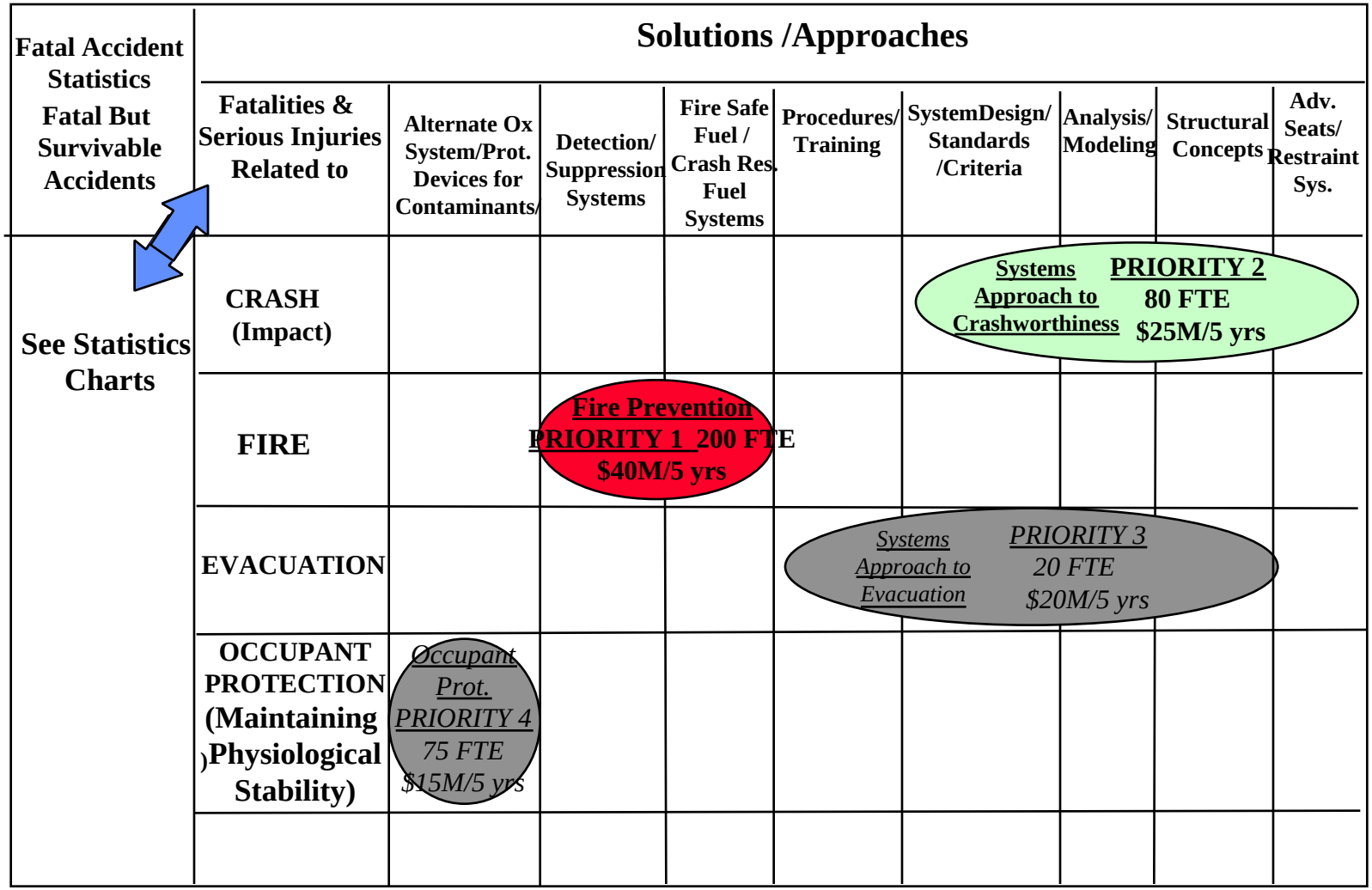
  All the Challenges/Objectives Are Aimed At Mitigation/Reduction of and Serious Injuries In Current As Well As New Aircraft Configurations.

Accident Mitigation

Human Survivability (HS) Proposed Investments



Human Survivability (HS) Proposed Investments



A. Objectives and Proposals in FIRE PREVENTION.

Objective *:*

To Identify, Support, and Develop Fire Prevention, Detection & Suppression Concepts That Can Minimize Fire Hazards In Crashes and In-Flight Incidents.

MITIGATION -- HUMAN SURVIVABILITY INVESTMENT OVAL

FIRE PREVENTION

FY	98	99	00	01	02	03	04
$$M			$4M	$8M	$10M	$13M	$5M	
FTE				12	24	30		40	15

SKILL MIX : Fire Protection Engineers, Mechanical Engineers, Materials Engineer, Polymer Chemists, Aerospace Engineers

B. Objectives and Proposals in SYSTEMS APPROACH TO CRASHWORTHINESS.

Objective *:*

To Develop A Systems Approach To Crashworthiness Design That Includes Validated Analysis Methodology, New Structural Concepts And Materials, Safer Cabin Interiors Design, Advanced Restraint Equipment, Design And Injury Criteria.

Why A Systems Approach to Crashworthiness ??

- **Significant Interactions Exist Between:**
  - **Occupant Response**

- **Seat Response**
- **Restraint System Performance**
- **Airframe Response**
- **Impact Surface (b.c.)**
- **Flight Conditions at Impact (i.c.)**

- **Critical Needs:**
  - **Injury Criteria**
  - **Component Performance**
  - **Simulation Tools (Integration)**

MITIGATION -- HUMAN SURVIVABILITY
INVESTMENT OVAL

SYSTEMS APPROACH TO CRASHWORTHINESS

FY	98	99	00	01	02	03	04
$$M		$3M	$5M	$6M	$8M	$3M	
FTE		9	15	18	24	9	

SKILL MIX : Impact Dynamics (Crash) Analysts, Test Engineers, Computer Systems Analysts, Structural Mechanics Engineers, Lab/Facility Technicians, Pyrotechnic Technicians, Photographers, Surveyors, Instrumentation & Data Acquisition Personnel (Contract).

C. Objectives and Proposals in EVACUATION.

<u>Objective</u>:

To Develop A Systems Approach For Evacuation That Includes Analysis/Simulation Methodology, New Procedures ,Training, Equipment, And Design Criteria Which Can Enhance And Provide Means For More Timely Evacuation During Fire In Aircraft Accidents And Thus Mitigate/Reduce Fatalities and Serious Injuries In Current As Well As New Aircraft Configurations.

Why a Systems Approach to Evacuation ??

- **Need to Consider All Aspects of Evacuation**

- **Equipment**
- **Procedures**
- **Training**
- **Dependencies Between Equipments & Humans**

- **Permits Evacuation Considerations Early in the Design Cycle for New and Derivative Aircraft.**
- **Proposed New Designs (Multi-aisle, Multi-deck Aircraft, i.e. Blended Wing) Will Present Evacuation Design Challenges Not Confronted With Contemporary Designs.**

D. Objectives and Proposals in OCCUPANT PROTECTION.

<u>Objective</u>:

To Develop Detection/Warning Means, New Procedures ,Training, And Equipment Which Can Provide Occupant Protection From Fire Related Hazards And Thus Provide Additional Evacuation Time Thereby Mitigating Or Reducing Fatalities and Serious Injuries In Current As Well As Future Aircraft Configurations.

9.0 Integrated Priorities Across All Major Issues

The following list is an Integrated Priority of Focuses in Human Survivability to Address the Fatalities and Serious Injuries in Fatal But Survivable Accidents.

Human Survivability (HS)

Prioritization Of Investment Areas Across The Major Four Human Survivability Issues

1. Fire Prevention (Pre/Post Incident) -- $40M/5yrs
   - **Crash Resistant Fuel Systems**
   - **Fire Safe Fuels/Systems**
   - **Fire Detection/Suppression**
   - **Fire Safe Materials**
2. Systems Approach To Crashworthiness -- $25M/5yrs
   - **Analytical Modeling**
   - **Metal/Composite Structures**
   - **Design Criteria/Guidelines**
   - **Biomechanics**
3. *Systems Approach To Evacuation -- $20M/5yrs*
   - ***Modeling***
   - ***Procedures/Training***
   - ***Equipment***
   - ***Exit/Slide Design Criteria***
   - ***Guidelines***
4. *(Occupant Protection) Maintaining Physiological Stability -- $15M/5yrs*
   - ***Alternate Ox Generation***
   - ***Protection from Contaminants***
   - ***Hypoxia***

10.0 Summary

Against An Assessment of Expected Big Pay- off Areas for Reducing Fatalities and Serious Injuries In Fatal But Survivable Aircraft Accidents, The Human Survivability Sub-Team :

- **Developed Overall Proposal Package For Human Survivability Initiatives For Consideration In a Portfolio Of Potential NASA Safety Investments.**

- **Used Statistics (As Possible), And Collective Judgement of Industry and Government Experts to Develop a Priority List of Efforts and Allocations Within Four Major Focus Areas.**

- **Proposed Systems Approaches, Where Possible, As Solution Path to Current Issues Which Also Will Help Address Future Human Survivability Issues.**

11.0 Appendix - Rotorcraft Inputs

Appendix A
Human Survivability Safety Investment Strategy
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1.0 Charter

For the Human Survivability sub-Team, the tacit assumption is that an accident has already occurred. Contrary to popular perception, a majority of aviation accidents are survivable, and not all people involved in fatal accidents are, themselves, fatalities. For example, 45% of world-wide transport accident that occurred between 1959 and 1990 were survivable. Of those accidents in which there were fatalities, 50% were due to impact and fire, 27% due to fire and smoke, 18% impact alone and 5% by

drowning. Therefore, an investment in the human survivability element can provide a significant contribution to the overall goal of decreasing the fatal accident rate.
In developing their investment strategy, the sub-Team identified four human survivability issues, in decreasing order of priority: (1) Fire, (2) Crashworthiness, (3) Evacuation, and (4) occupant protection reducing the fatal accident rate.
This sub-Team is led by Mr. Huey Carden (NASA-Langley Research Center, Phone: ; e-mail:). This team was composed of experts drawn almost equally from government and industry.

2.0 Rotorcraft Statistics provided

The most useful data I was able to obtain on the civil helicopter accident survivability issues was provided by Jerry Hordinsky (CAMI) based upon a data search he commissioned from NASDAC. The most interesting data is the number of fatal accidents in which there was at least one survivor. Such survivable accidents should be an early focus of this program. Particularly notable was the fact that as many as 21% of the RC were survivable whereas only 14% of the GA accidents were. (I assume the percentage would be even lower for A/L accidents, but do not have the data). This suggests that improving accident survivability would be a particularly fruitful area of investment to reduce the number of R/C fatalities.

Table 1: GA and Rotorcraft Accident Survivability (1985-1995, from NASDAC)

	GA-All	*GA-Rotorcraft*
Fatal Accidents	*4,979*	*359*
Fatal Accidents with At Least One Survivor On Board	*701*	*76*
Accidents with Fire	*2,624*	*194*
Fatal Accidents with Fire	*1,588*	*101*

*Accidents with Evacuation Issues**	*9*	*2*
*Fatal Accidents with Evacuation Issues**	*5*	*0*
*Accidents with Breathing Equipment Problems^*	*0*	*0*
*Fatal Accidents with Breathing Equipment Problems^*	*0*	*0*

* *References to evacuations that were not performed, had problems, or were premature*

^ *References to the oxygen system's breathing equipment*

Additional useful information can be gleaned from accident statistics provided by the Navy (Table 2). If all of the potentially survivable accidents are analyzed (e.g., accidents where forces transmitted to the human occupants do not exceed the limits of human tolerance and in which the structure immediately around him remains substantially intact), it appears that the overall victim survival rate increases to 75%. In most cases, serious or lethal injuries were sustained to the upper body, suggesting the benefits of improved restraint systems and crash attenuating seating. The UH-1 variants had a total of 11 survivable mishaps between 1985-1995 - - 64% of the crew and 73% of the passengers sustained injuries. Even though life rafts were onboard, only a few were deployed and the percentage of "lost at sea" was the highest for any other vehicle type. For the different variants of the H-46, there were 34 survivable mishaps between 1985-1995. Survival rates

Table 2: Summary of Navy and Marine Class A Mishaps (1985-1995)

	AH-1	**H-1**	**H-46**	**H-53**	**H-60**	**Total**
*Class A Mishaps **						
Day	*6*	*12*	*27*	*22*	*10*	*77*
Night	*8*	*10*	*17*	*4*	*8*	*47*
Over land						
Survivable	*4*	*4*	*16*	*13*	*3*	*40*
Non-survivable	*7*	*7*	*8*	*5*	*1*	*28*

Over water						
Survivable	*2*	*7*	*18*	*4*	*13*	*44*
Non-survivable	*1*	*4*	*2*	*4*	*1*	*12*

1985-1995 Navy & Marine helicopter Class A mishaps (Kinker et al)

** fatality, permanent disability, or total property damage >$1M*

were 30% higher for over-land accidents than for over-water accidents, again pointing to the importance of a rotorcraft safety investment in water crash survival. In the survivable water mishaps that occurred between 1985 and 1995, 43 were due to thermal exposure, 20 to drowning and 46 "lost at sea". The latter might be influenced by poor seating and restraint, lack of egress training, poor exit/escape design, and so on.

3.0 Current needs assessment

Within each of the four prioritized human survivability issues, specific issues were identified:
Fire: Crash resistant fuel systems, fire detection and suppression, fire-safe fuels and oxygen systems, and fire-resistant aircraft materials. These issues are as relevant to rotorcraft as to other vehicle classes.
Crashworthiness: Adopting a systems approach that includes analytical modeling, developing metal and composite structures, design criteria and guidelines, and performing research on biomechanics for traditional as well as non-traditional aircraft types and configurations. A systems approach was adopted because there are significant interactions among the responses of the occupants, seats, restraints, airframe, impact surface, and flight conditions at impact. The critical needs in this area are better injury criteria, information about component performance and integrated simulation tools. All of these issues are important in R/C survivability.
Evacuation: With this area as well, a systems approach must be adopted to address all aspects of evacuation; equipment, procedures, training, and dependencies between equipment and humans. This approach will permit evacuation considerations early in the design cycle for new as well as derivative aircraft. The primary issues are water-related survivability and post-crash

rescue. Although the ground infrastructure is an important issue as well, it is not being addressed by this group. All of these issues are important to R/C survivability.
Occupant protection: The two primary issues under consideration in this area are crew hypoxia and the use of protective breathing equipment. These issues may not be as relevant for R/C as for other vehicle classes.

4.0 Current R&D Assessment

The US Navy Advanced Crashworthy Aircrew Survival System Program is actively addressing many of the issues enumerated above: body harness restraint system with a powered inertia reel, airbags, more effective egress methods (such as emergency hatch designs, lighting), crash attenuating seat designs, life deployment systems (for 3 or the 5 types of helicopters surveyed, no life raft was ever deployed during a mishap), retrofitable crashworthy fuel system to reduce the likelihood of post-crash fires, and water survival training. The latter might be accomplished by a reconfigurable, portable device (like the Canadian Modular Egress Training Simulator). The Navy is the most active service in conducting crash survivability research - - $1-1.3M/year. It would appear that the most productive approach that NASA might take would be to work with the Navy to ensure that technology transfer from their results to the civil helicopter community was effective and to perform supplementary research where necessary to develop a civilian counterpart to a product tailored to a military application.

5.0 Future Needs Assessment

6.0 Near-term investment strategy